Software Requirements Specification (SRS)

Active Park Assist (APA 1)

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1 Introduction

Active Park Assist (APA) is a system that eliminates driver error to ensure that vehicle parking can be carried out in an accurate and safe manner. APA allows a driver to park a vehicle with minimal interaction by using sensors to detect nearby empty parking spaces and detect obstacles in its path during the parking operation. To describe key features, functionality, and how subcomponents of the system interact, this document details the requirements, functionality, elements, and uses of APA that assists drivers to park their vehicles with minimal interaction.

1.1 Purpose

The purpose of this Software Requirements Specification (SRS) document is to outline the requirements and models to define our system. Our SRS includes a use case diagram, a domain model, a sequence diagram, state diagrams, and prototypes/scenarios. These diagrams and models represent different aspects of our SRS and are intended to help readers understand the SRS. Our intended audience is the stakeholders, Dr. Cheng, Ms. Eileen Davidson from Ford.

1.2 Scope

APA is an embedded system that is designed to leverage existing technology on a vehicle, such as sensors and cameras, to automatically park the vehicle with minimal driver interaction. To achieve this, the APA system has control of subsystems such as steering, braking, and acceleration. To activate the APA system, the customer interacts only with the Human Machine Interface (HMI). When engaged by the driver, the APA processes camera feed and sensor data from onboard sensors to identify nearby empty parking spots by calculating the distance between vehicles to determine if there is enough space to park. Once an empty spot has been identified, the driver verifies it using the HMI. While the APA system is engaged, sensors detect obstacles in the path of the vehicle and respond with warnings to the driver through sound alerts on the speakers and visual alerts on the HMI. If an obstacle is detected in the path of the vehicle or the driver engages the brakes, the APA is disengaged. The APA system only supports parallel or perpendicular parking.

1.3 Definitions, acronyms, and abbreviations

Software Requirements System - SRS
-The SRS is our document where we describe the functionality of our system
Active Park Assist - APA
-APA is the system that eliminates driver error to ensure safe parking
Human Machine Interface - HMI
-HMI is a display that interacts with the user
Unified Modeling Language - UML
-UML is the modeling language we use
Park Control Subsystem - PCS
-Accepts the input from the HMI and issues commands to the other subsystems
Powertrain Management Subsystem - PMS
-Accelerates the vehicle and selects the gear position for the required trajectory
Brake Control System - BCS
-Brakes the vehicle with the required trajectory
Steering Control Subsystem - SCS
-Steers the vehicle with the required trajectory
Vehicle Position Subsystem - VPS
-Gathers data from the vehicles cameras to identify parking spots and verifies the vehicles position while parking is occurring.

1.4 Organization

The remainder of the document is organized as follows. Section 2 describes the major functionality of APA. Section 3 provides a list of enumerated requirements. Section 4 models the requirements from the previous section. Section 5 shows a rapid prototype for how the system shall behave in the scenarios described. Section 6 provides credit to the resources referenced in the making of this system. Section 7 provides a point of contact for further information about this project.

2 Overall Description

In this section we overview different parts of the system. In Section 2.1, we cover the product perspective and describe how our system operates on a general scale. In Section 2.2, the product functions and the main purpose of the system is described. Section 2.3 covers the user characteristics and how a user would go about using the system. Section 2.4 describes the constraints regarding the system. Section 2.5 describes some assumptions we will make about the system. Section 2.6 describes the appropriate requirements needed for this system.

2.1 Product Perspective

The APA system refers to the set of cameras, sensors, software, and hardware that minimize driver interaction by automating the parking process in an accurate and safe manner. The APA system has inputs such as sensor data from onboard sensors and visual feed from front and rear cameras. Additionally, the APA system has access and control to subsystems of the vehicle such as the powertrain, HMI, brakes, and steering. The APA system has hardware constraints. Radar sensors must be placed around the vehicle and cameras installed at the front and back of the vehicle to observe the environment. There are also communication constraints; every subsystem must have software to allow for operation and communication within the APA system. Finally, the size of the vehicle's memory limits the system size and the amount of space available for data.

2.2 Product Functions

Active Park Assist is used to eliminate the driver error that is involved when parking a vehicle. This system allows a car to be parked in a safe manner without the driver themselves having to park. There are a few steps that occur before the parking maneuvers actually occur. The driver interacts with the HMI (Human Machine Interface) which allows the driver to choose the type of parking they would like to occur (parallel or perpendicular). After this interaction, the HMI will identify the parking spot, accelerate or decelerate the car, choose between forward or reverse, and eventually steer the vehicle into the applicable parking spot. While the car is being maneuvered into the spot determined by the system, the onboard sensors and cameras on the front and the rear of the vehicle monitor the position of the vehicle and ensure that the vehicle parks in the correct location. While the APA is active, the driver does not have control of the vehicle itself, the only thing they do control is the brake pedal which if used can disengage the APA system and let the user gain control of the vehicle again. The driver of the vehicle can also transfer the control via the Ford Pass mobile app which they can install on their respective cell phones. This app allows for the control of speed and position of the vehicle to be done with the driver out of the vehicle. During the use of the APA system we see the use of several subsystems. These include the Park Control system (PCS), Powertrain Management Subsystem (PMS), the HMI subsystem, Brake Control Subsystem (BCS), Steering Control Subsystem (SCS), and the Vehicle Position Subsystem (VPS).

2.3 User Characteristics

The APA system has some expectations for its users. The user of the system (the driver) is assumed to be legally authorized to operate the vehicle. The user must be alert at all times and pay attention to the warnings displayed on the HMI screen and/or the auditory warnings played over the speakers. Additionally, the user must take the initiative to override the APA system if it starts to fail or is taking longer than it needs to.

2.4 Constraints

The APA system has many constraints that limit its functionality. For example, the system is active only when the driver verifies the request through the HMI. Also, the system only supports parallel and perpendicular parking. The vehicle maintains a maximum speed, and the customer can slow that speed via the brake. The system will not work if failure is detected in any of the sensors. The system will disengage after a period of time if it fails to park the vehicle. In order to parallel park, there must be an empty space that is at least 1.2x the length of the vehicle.

2.5 Assumptions and Dependencies

An assumption we have made is how it is assumed that all of the subsystems already are installed and work properly. Additionally, it is assumed that the software will be up to date on the vehicle. Finally, the driver is assumed to operate the vehicle under the conditions presented.

2.6 Apportioning of Requirements

Additional requirements could be added on in the future to keep up to date with the needs of the stakeholders.

3 Specific Requirements

The following section lists the specific requirements for the APA system and enumerates the specific details regarding the needs of the system.

1. The system should work for both parallel and perpendicular parking spaces.
2. The system shall include an HMI
    a. The driver will initiate the system via the HMI by selecting the desired parking type.
    b. APA will only start when the driver has initiated and verified the maneuver based on the identified spots portrayed to the user on the HMI.
    c. If no suitable spot is found, the system will alert the driver and the system will deactivate.
    d. The HMI should display the camera feed when maneuvering.
    e. HMI should have a full override option from the driver where the driver is able to completely retake control of the vehicle.
3. The system shall verify that the parking spot that is desired shall be clear of obstacles before the system begins the maneuver.
4. The system will use 4 wide-angle cameras placed on each side mirror, the rear hatch, and the grille on the front of the vehicle to create the birds-eye view of the vehicle.
5. Ultrasonic sensors should be mounted on the side of the vehicle to measure if spaces have the proper amount of space to fit our vehicle.
    a. The space must be greater than 1.2x the length of the vehicle.
    b. The space must have 3 feet of room on each side of the vehicle.
6. Cameras and sensors will continuously monitor surroundings of the vehicle while the system is active.
7. The cameras and sensors shall be able to identify obstacles and humans that have moved into the path of the vehicle during a parking maneuver.
    a. If an obstacle is obstructing the desired parking space during the parking operation, then the car will stop until the obstacle is removed.
    b. If the vehicle moves within 10 inches of any obstacle that is outside of the parking space, it will stop, back up, and use the sensors to readjust.
8. The system needs access to the Park Control Subsystem, Powertrain Management Subsystem, Brake Control Subsystem, Steering Control Subsystem, and Vehicle Position Subsystem to control movement of the vehicle.

9. The system needs to be able to park the car in both forward and reverse (pull in and back in).
10. After the parking operation has been successfully terminated, the system shall deactivate.
11. The max speed of the vehicle during active park assist is 5 mph.
    a. As the vehicle moves within 6 feet of a neighboring vehicle, it will slow to 2 mph.
    b. As the vehicle moves within 3 feet of a neighboring vehicle, it will slow to <1 mph.
12. During a parking operation, the driver may slow or stop the car by applying the brakes.
13. An application shall be created for the cell phone which allows the driver to control speed and position while outside the vehicle and allow the driver to initiate the system.
14. To ensure security of this application, the application shall be linked to the driver's password protected account in order to only allow operation from this account.
15. If a failure is thrown from any of the car's subsystems during a parking maneuver which directly affects a functionality of the APA system, the parking maneuver should not continue and the driver should be notified of the failure via HMI.
16. The system must be able perform necessary calculations such as radius of turn and angle of steering in order to park the vehicle.
17. Cameras and sensors should be resistant to below freezing or very hot conditions.

4 Modeling Requirements

This section captures the requirements of the APA system visually. The use case diagram provides a high level view of the visual functionality of the system. The domain model expresses the high level structure of the system's components. The sequence diagrams show the flow through the system when faced with specific scenarios. The state diagrams show the flow through the different states of each of the main components in the system.

4.1 Use Case Diagram

Figure 1 shows a representation of the high-level functionalities of the APA system through a use case diagram. The system boundary is represented by the blue box, which is the APA system. The use cases are represented by the ovals within the system boundary. The actors are represented by the stick figures on the outside of the boundary. The different interactions between actors and use cases are expressed by the lines and arrows as seen in the diagram.

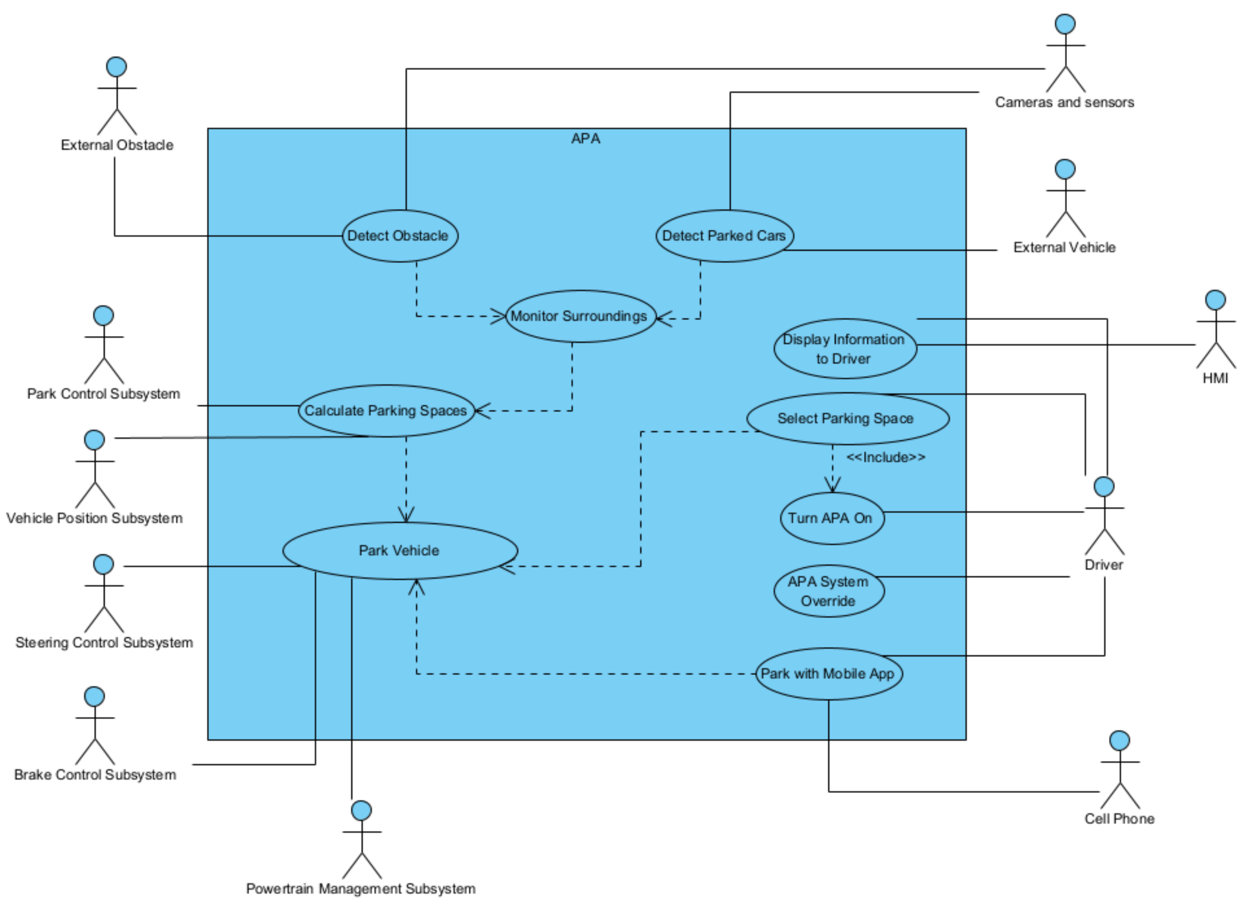

Figure 1: Use Case Diagram

Table 1: Description for use case: Detect Obstacle

Use Case:	Detect Obstacle
Actors:	External obstacle, cameras and sensors.
Description:	System will be able to detect obstacles and be sure that no obstacles are in the way of detected parking spots. This will be accomplished by way of 4 wide-angle cameras to allow full external coverage of the vehicle. Sensors will also be used for this detection. Obstacles that move into the way during a maneuver will be detected. This should work in abnormally hot or cold conditions.
Type:	Secondary
Includes:	N/A
Extends:	N/A
Cross-refs:	3, 4, 7, 7a, 7b, 17
Use Cases:	Monitor surroundings, calculate parking spaces, park vehicle

Table 2: Description for use case: Detect Parked Cars

Use Case:	Detect Parked Cars
Actors:	External vehicle, cameras and sensors
Description:	The system should detect cars for both parallel and perpendicular parking spaces. Sensors should be able to ensure spaces have enough room for the vehicle (1.2x length of car and 3 feet of room on each side). This should work in abnormally hot or cold conditions.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	1, 5, 5a, 5b, 17

Use Cases:	Monitor surroundings, calculate parking spaces, park vehicle

Table 3: Description for use case: Monitor Surroundings

Use Case:	Monitor Surroundings
Actors:	N/A
Description:	The system should monitor the surroundings of the vehicle constantly when APA is active. This includes both the detection of obstacles and parked cars to validate parking spaces.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	6
Use Cases:	Calculate parking spaces, park vehicle

Table 4: Description for use case: Calculate Parking Spaces

Use Case:	Calculate Parking Spaces
Actors:	Park control subsystem, vehicle position subsystem
Description:	System should be able to perform necessary calculations such as radius of turn and angle of steering to complete parking maneuver.
Type:	Secondary
Includes:	N/A
Extends:	N/A
Cross-refs:	16
Use Cases:	Park vehicle, select parking space

Table 5: Description for use case: Park Vehicle

Use Case:	Park Vehicle
Actors:	Steering control subsystem, Brake control subsystem, powertrain management subsystem
Description:	System should be able to park in both parallel and perpendicular parking spaces and be able to go in reverse and forward. This requires access to the accelerator, steering, and brakes. System will deactivate and put the car in park after parking the vehicle. Max speed during APA will be 5 mph. As the vehicle moves within 6 feet of a neighboring vehicle, it will slow to 2 mph. Within 3 feet, it will slow to <1 mph.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	1, 8, 9, 10, 11, 11a, 11b
Use Cases:	N/A

Table 6: Description for use case: Display Information to Driver

Use Case:	Display Information to Driver
Actors:	HMI, Driver
Description:	HMI will display information to the driver. This includes parking options, ability to initiate the system, alerts on if parking spaces are found or not, and camera feed. Will display any system failures to the driver via the HMI. Information can also be displayed through the Ford App for the system.
Type:	Secondary
Includes:	N/A
Extends:	N/A
Cross-refs:	2, 2a, 2b, 2c, 2d, 2e, 13, 15

Use Cases:	N/A

Table 7: Description for use case: Select Parking Space

Use Case:	Select Parking Space
Actors:	Driver
Description:	The driver will be able to select a parking space after a valid space is found from the system after the driver has turned on the system. The driver will also be able to select the parking space via the Ford App.
Type:	Primary
Includes:	Turn APA On
Extends:	N/A
Cross-refs:	2, 2b, 13
Use Cases:	Park vehicle

Table 8: Description for use case: Turn APA On

Use Case:	Turn APA On
Actors:	Driver
Description:	The driver should be able to turn on the system via the HMI and also be able to initiate the system via the HMI.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	2a, 13
Use Cases:	Select parking space, park vehicle

Table 9: Description for use case: APA System Override

Use Case:	APA System Override
Actors:	Driver
Description:	The driver should have braking access during a maneuver. The driver shall also be able to completely override the system during a maneuver if they choose to.
Type:	Secondary
Includes:	N/A
Extends:	N/A
Cross-refs:	2e, 12
Use Cases:	N/A

Table 10: Description for use case: Park with Mobile App

Use Case:	Park With Mobile App
Actors:	Driver
Description:	Application will allow the driver to control speed and position from outside of the vehicle, along with the ability to initiate the system. The app should be secured by a password protected account of the driver linked to the app so that outsiders cannot easily control the system.
Type:	Secondary
Includes:	N/A
Extends:	N/A
Cross-refs:	13, 14
Use Cases:	N/A

4.2 Domain Model

The following domain model in Figure 2 demonstrates the structure of the APA system in the form of a UML class diagram. The blue boxes correspond to components of our system with the lines representing different types of interactions between the system's several components. The line with the black diamond represents a composition. The lines with a white diamond represent aggregation connections. The normal lines represent simple associations within our system. The overall goal of this model is to show how the different pieces of our system interact in order for our system to work as intended.

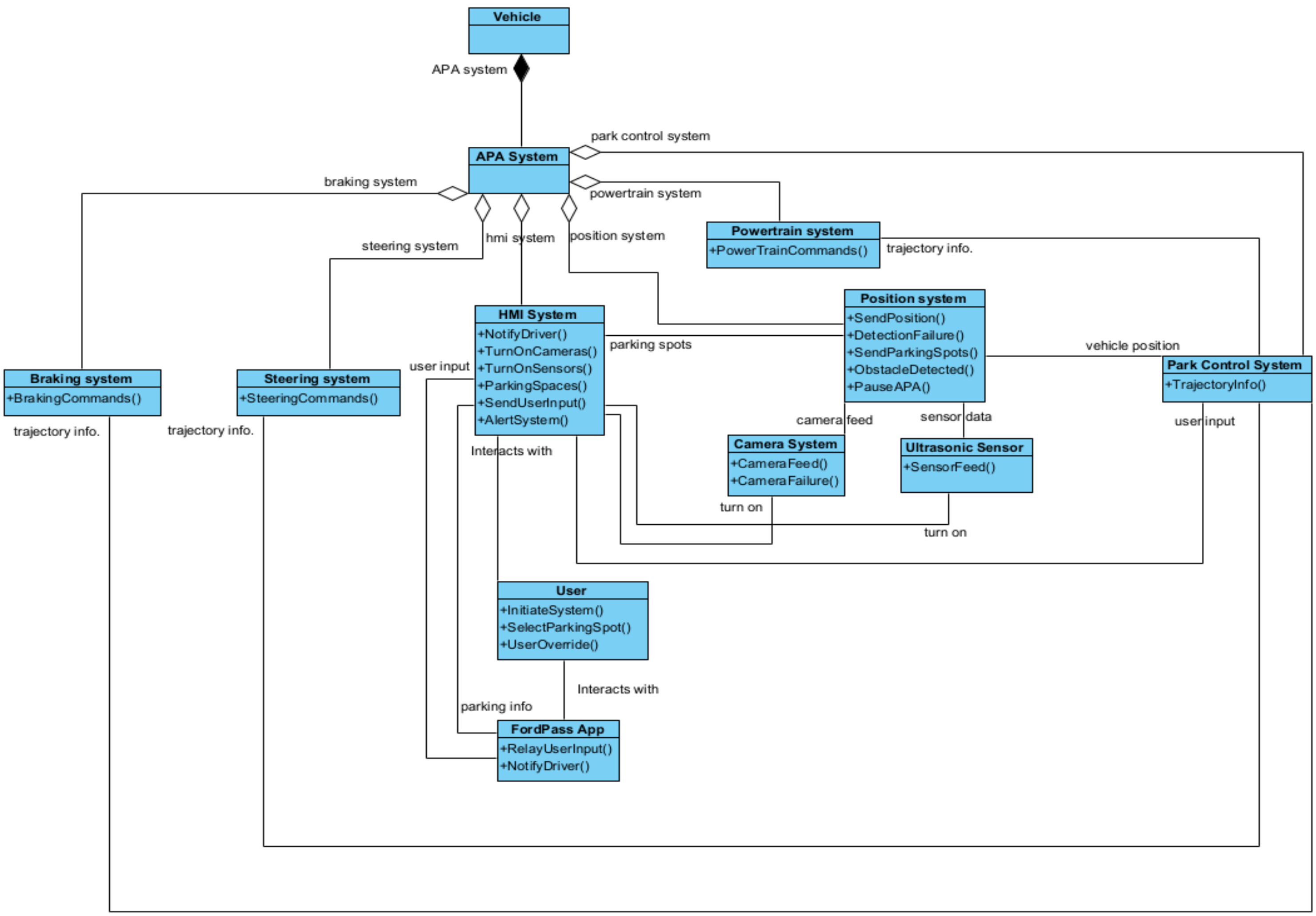

Figure 2: Domain Model

Table 11: Description for component: Vehicle

Name	Vehicle
Description	The vehicle that our system is inside of.
Relationships	Composition: APA System - The vehicle contains the APA system.
Attributes	
Operations	

Table 12: Description for component: APA System

Name	APA System
Description	The APA system itself.
Relationships	Composition: Vehicle - The vehicle contains to APA system itself. Aggregation: Braking System, Steering System, HMI System, Position System, Powertrain System, Park Control System - The APA system directly contains all of these subsystems, but they are also used in other systems of the car.
Attributes	
Operations	

Table 13: Description for component: Powertrain System

Name	Powertrain System
Description	Accelerate the vehicle and select the gear lever position in order to meet the required trajectory.
Relationships	Aggregation: APA System - APA system contains this subsystem. Association: Park Control System - Accepts input from the

	park control system in order to perform its functions.
Attributes	
Operations	PowerTrainCommands() - Send powertrain commands to the APA system

Table 14: Description for component: Braking System

Name	Braking System
Description	Brakes the vehicle in order to meet the required trajectory for parking.
Relationships	Aggregation: APA System - APA system contains this subsystem. Association: Park Control System - Accepts input from the park control system in order to perform its functions.
Attributes	
Operations	BrakingCommands() - Send braking commands to the APA system

Table 15: Description for component: Steering System

Name	Steering System
Description	Steer the vehicle in order to meet the required trajectory for parking.
Relationships	Aggregation: APA System - APA system contains this subsystem. Association: Park Control System - Accepts input from the park control system in order to perform its functions.
Attributes	
Operations	SteeringCommands() - Send steering commands to the APA system

Table 16: Description for component: HMI System

Name	HMI System
Description	Accepts customer inputs, displays camera information, and handles telltales / warnings.
Relationships	Aggregation: APA System - APA system contains this subsystem. Association: User - The user interacts with the HMI Park Control System - HMI sends user input to this system. FordPass App - Parking information is sent to the ford app along with user input from the app being sent to the HMI. Position System - HMI receives identified available parking spots. Camera System/Ultrasonic Sensors - System turns these systems on when the user starts APA.
Attributes	
Operations	NotifyDriver() - Notifies driver of any information TurnOnCameras() - Turns on cameras TurnOnSensors() - Turns on sensors ParkingSpaces() - Sends parking spaces to the mobile app SendUserInput() - Sends user input to park control system AlertSystem() - Alerts the system of information (ex: user override)

Table 17: Description for component: Position System

Name	Position System
Description	Processes data from the vehicle's cameras / sensors in order to identify parking spots and verify vehicle position throughout the duration of a parking event.
Relationships	Aggregation: APA System - APA system contains this subsystem. Association:

	HMI System - HMI receives identified available parking spots. Camera System - Camera feed is accepted to be processed in this system. Ultrasonic Sensor - Sensor data is accepted to be processed in this system. Park Control System - Position information is sent to park control system.
Attributes	
Operations	SendPosition() - Send position to park control system DetectionFailure() - True/False for system failures, such as camera failure SendParkingSpots() - Send parking spots to HMI ObstacleDetected() - True/False if obstacle has been detected by cameras/sensors PauseAPA() - Pauses APA system

Table 18: Description for component: Park Control System

Name	Park Control System
Description	Accepts the customer input from the HMI subsystem, calculates the vehicle trajectory based on information from the Vehicle Position Subsystem, and issues commands to the other subsystems.
Relationships	Aggregation: APA System - APA system contains this subsystem. Association: Powertrain System - Sends trajectory information to the powertrain system. Position System - Accepts vehicle position information from the position system. HMI System - Accepts user input information from the HMI. Steering System - Sends trajectory information to the steering system. Braking System - Sends trajectory information to the braking system.
Attributes	
Operations	TrajectoryInfo() - Sends out trajectory info to

	other subsystems

Table 19: Description for component: Camera System

Name	Camera System
Description	Contains the cameras and feeds the camera feed to the rest of the system.
Relationships	Association: Position system - Sends camera feed to the position system. HMI System - Camera system is turned on when the user initiates APA through the HMI.
Attributes	
Operations	CameraFeed() - Sends camera feed to position system CameraFailure() - detects camera failure

Table 20: Description for component: Ultrasonic Sensor

Name	Ultrasonic Sensor
Description	Contains the sensors used for detecting external objects.
Relationships	Association: Position system - Sends sensor information to the position system. HMI System - Sensors are turned on when the user initiates APA through the HMI.
Attributes	
Operations	SensorFeed() - sends sensor feed to position system

Table 21: Description for component: User

Name	User
Description	The user that is interacting with the system.
Relationships	Association: HMI System - User interacts with the HMI. FordPass App - User interacts with the app to control APA.

Attributes	
Operations	InitiateSystem() - User initiates the system SelectedParkingSpot() - User selects the parking space UserOverride() - User overrides the system

Table 22: Description for component: Ford Pass App

Name	Ford Pass App
Description	The app that can be used to access the APA system from outside of the vehicle.
Relationships	User - User interacts with the app to control APA. HMI System - Parking information is sent to the ford app along with user input from the app being sent to the HMI.
Attributes	
Operations	RelayUserInput() - relays user input to the HMI NotifyDriver() - Notify driver of important parking info/updates

4.3 Sequence Diagrams

The following section lists several common scenarios that may be encountered and contains a sequence diagram to visually express how our system will handle these situations. The blue boxes represent objects within our system, and the arrows represent movement through the system and the interactions between the different objects that are used for the specific scenario.

4.3.1 Normal Parking Scenario

Figure 3 below represents the system in a normal parking scenario in a perpendicular parking space where there is a car on either side of the parking space and the space is a valid size. The system is initiated by the user interacting with the HMI system. The system will turn on the cameras and sensors from there and the camera and sensor feed will be sent to the position system. The system will detect parkings spots and send this information to the HMI, notifying the driver. The user will select the desired parking spot and this information will be sent to the park control system. The vehicle position will continually be sent to the park control system after this, which will allow trajectory information to be passed to the powertrain, braking, and steering systems. From there, the information will allow those subsystems to navigate the car to the desired parking spot.

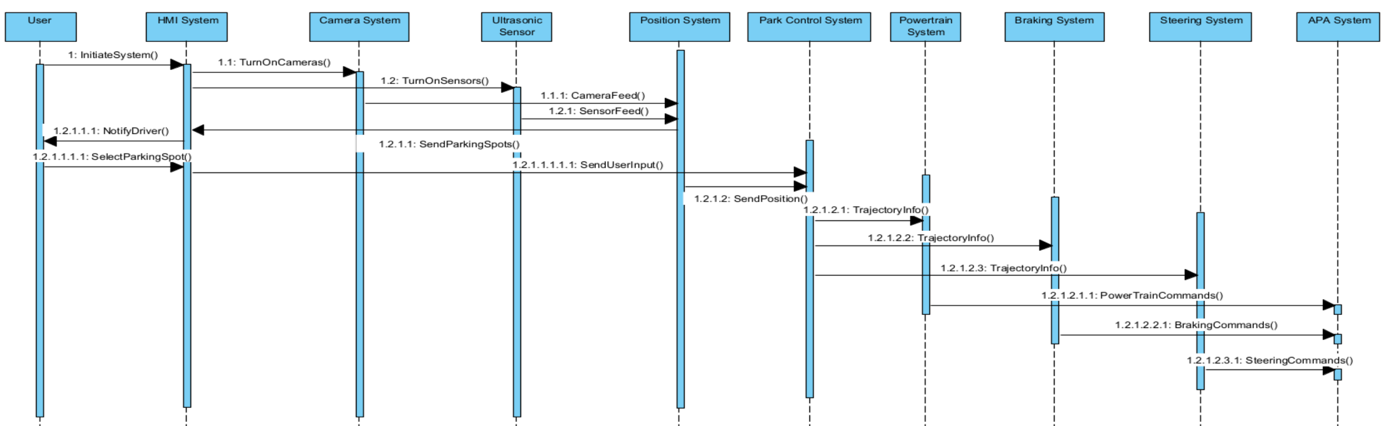

Figure 3: Sequence diagram for a normal parking scenario

4.3.2 Parking with the FordPass App

Figure 4 below represents the system under normal, working conditions using the FordPass mobile app to park into a valid parallel parking space. The system begins when the user interacts with the FordPass app to start the system. This activation is relayed to the HMI which then triggers the cameras and sensors to turn on, which then starts sending camera and sensor feed to the position system. Detected parking spots are then sent back to the HMI and relayed to the FordPass app interface. The user will select the desired parking spot from the app and this information will be relayed to the HMI and sent to the park control system. The vehicle position will continually be sent to the park control system after this, which will allow trajectory information to be passed to the powertrain, braking, and steering systems. From there, the information will allow those subsystems to navigate the car to the desired parking spot.

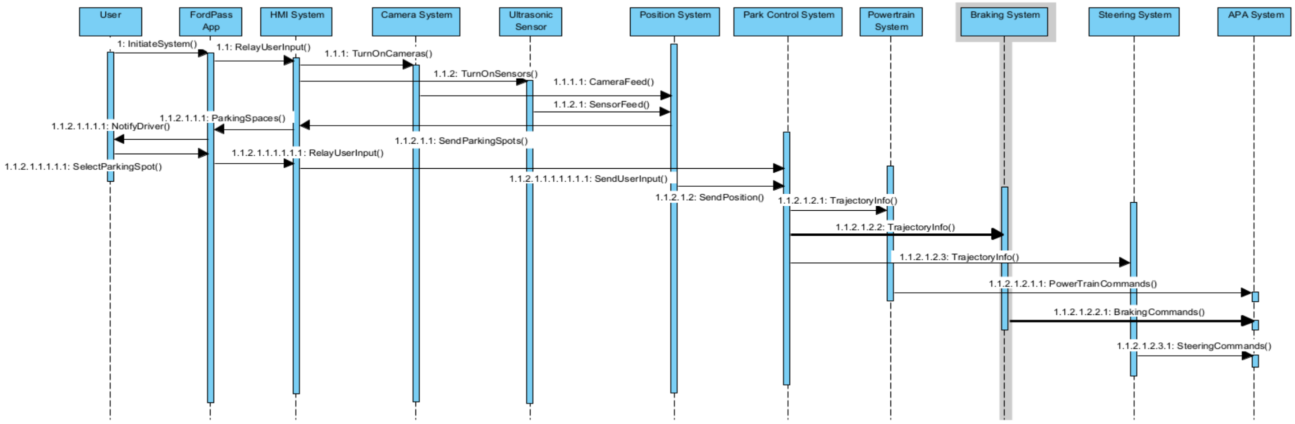

Figure 4: Sequence diagram for a normal parking scenario using FordPass app

4.3.3 Parking Scenario with a User Override

Figure 5 below represents the system in the case that an obstacle is close to the car during a maneuver and the driver is worried and decides to perform a full override of the system during the movement in order to exit the system. The system is initiated by the user interacting with the HMI system. The system will turn on the cameras and sensors from there and the camera and sensor feed will be sent to the position system. The system will detect parkings spots and send this information to the HMI, notifying the driver. The user will select the desired parking spot and this information will be sent to the park control system. The vehicle position will continually be sent to the park control system after this, which will allow trajectory information to be passed to the powertrain, braking, and steering systems. During the movement, the user interrupts the system through the HMI and overrides the system. This action alerts the APA system, which deactivates the system, giving the user full control of the vehicle.

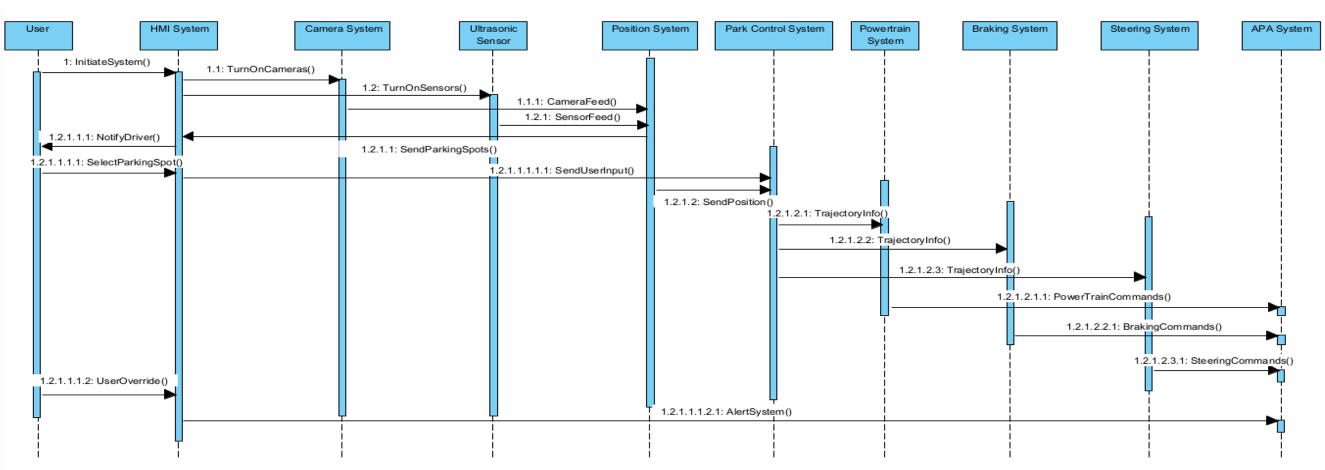

Figure 5: Sequence diagram for a scenario using driver override

4.3.4 A Camera Failure is Detected

Figure 6 below represents the system if there is a failure in the camera system that is detected when the driver activates the APA system via the HMI. The user begins by activating the system via the HMI. This triggers the cameras and sensors to turn on. The camera error will be detected and the position system will be notified of this failure. This information will be passed to the HMI system in order to notify the driver of this failure. The APA system will then be alerted and the system will deactivate due to the subsystem failure.

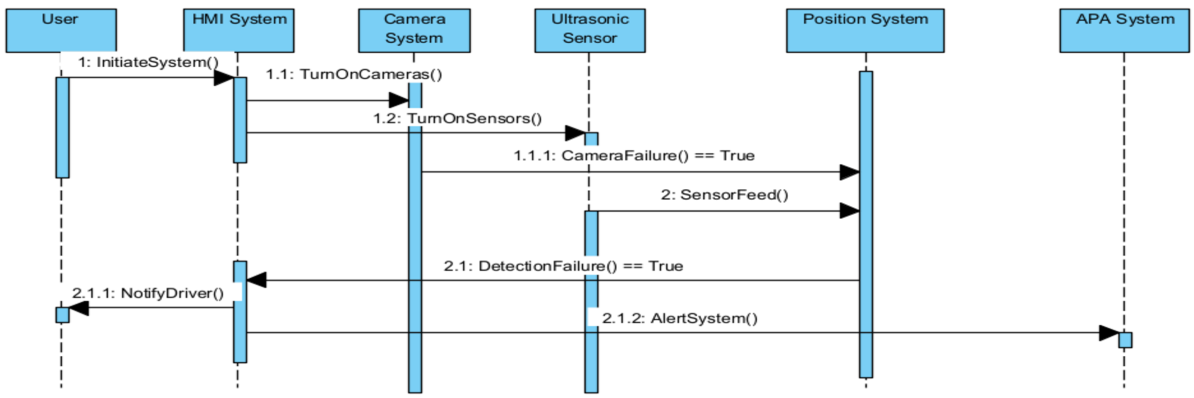

Figure 6: Sequence diagram for a scenario where there is a camera failure

4.3.5 No Valid Parking Spaces are Identified

Figure 7 below represents the system in the case that the sensors and cameras are unable to detect any valid parking spaces within range of the car. The user will begin by activating the system via the HMI. This triggers the cameras and sensors to turn on, allowing camera feed and sensor feed to be delivered to the position system. No parking spot will be detected, so the HMI will be sent this information to alert the driver, and then the APA system will be alerted and deactivated.

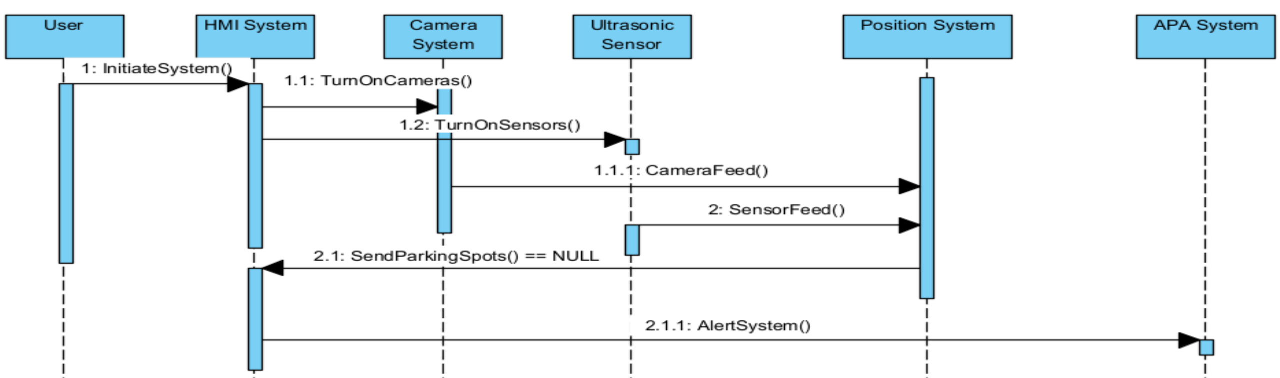

Figure 7: Sequence diagram for when there are no available parking spaces

4.3.6 An External Person Interrupts the Parking Operation

Figure 8 below represents the system in the case that a person walks behind the vehicle during the parking maneuver, blocking the targeted parking space. The person then moves out of the way of the vehicle, clearing the parking space. The system is initiated by the user interacting with the HMI system. The system will turn on the cameras and sensors from there and the camera and sensor feed will be sent to the position system. The system will detect parkings spots and send this information to the HMI, notifying the driver. The user will select the desired parking spot and this information will be sent to the park control system. The vehicle position will continually be sent to the park control system after this, which will allow trajectory information to be passed to the powertrain, braking, and steering systems. During the movement, a person walks in the way of the parking maneuver, so the position system recognizes this based on the camera and sensor feed and pauses the APA system. Once the person stops obstructing the parking space, the system will continue its parking movement.

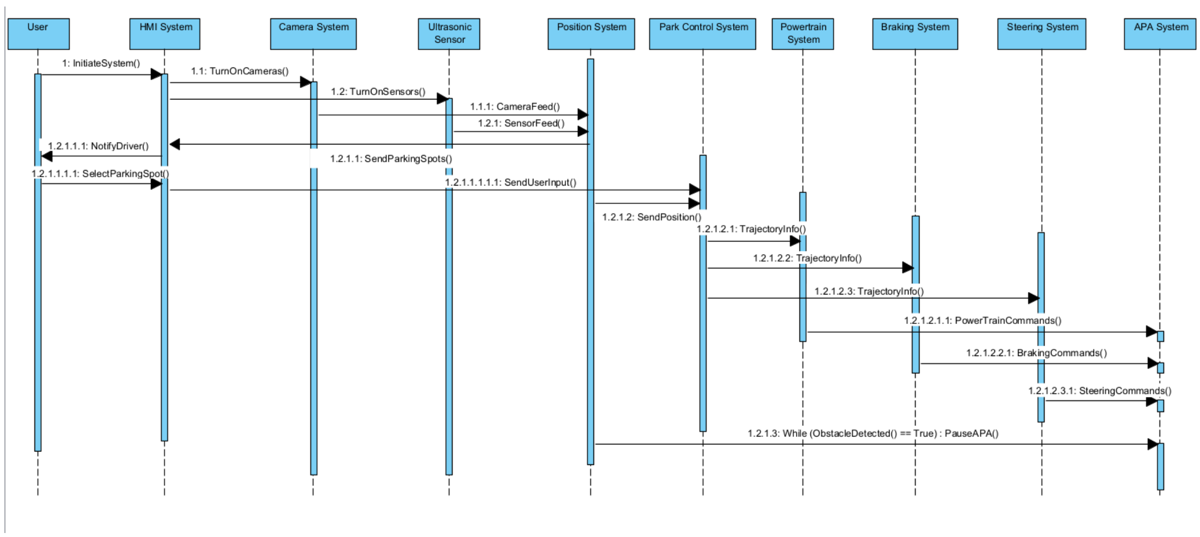

Figure 8: Sequence diagram for a person walking into the space during a maneuver

4.4 State Diagrams

The following section will contain several state diagrams for each of the main components of our system. Each state diagram will express visually how each component transitions between its states. The blue boxes represent the different states and the arrows express the transitions between the states.

4.4.1 APA System

The state diagram as seen in Figure 9 shows the different states for the APA system as a whole. The system can either be off, on, or paused. The system will shift from off to on when the user starts the system and from on to paused if an obstacle is detected that endangers the vehicle or blocks the parking space during the maneuver. The system will transition from paused to off when any obstacles are cleared from danger. Lastly, the system will go from the on state to the off state when the maneuver is completed or the user overrides the system.

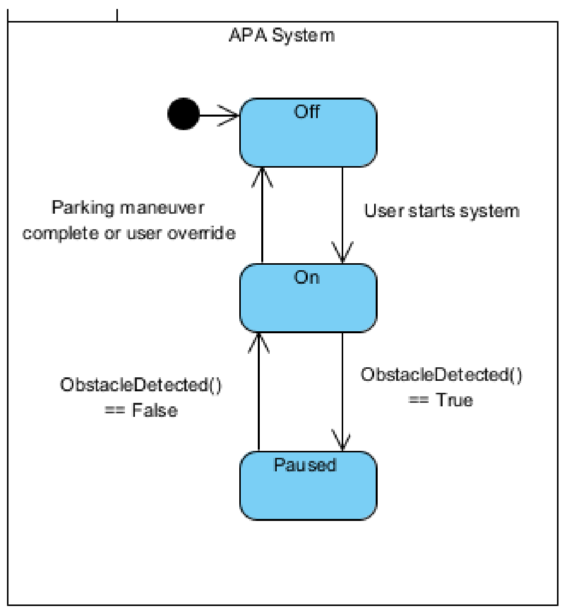

Figure 9: State diagram for the APA system

4.4.2 Braking System

The state diagram as seen in Figure 10 shows the different states for the braking system. The system will transition from the off state to the on state when brakes are applied and then back to the off state when the brakes are no longer being applied.

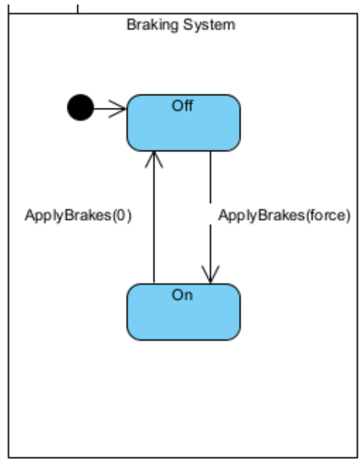

Figure 10: State diagram for the braking system

4.4.3 Powertrain System

The state diagram as seen in Figure 11 shows the different states for the powertrain system. The system contains four states which are park, reverse, neutral, and drive. These states are transitioned through each other as seen in the diagram when the gear of the car is switched.

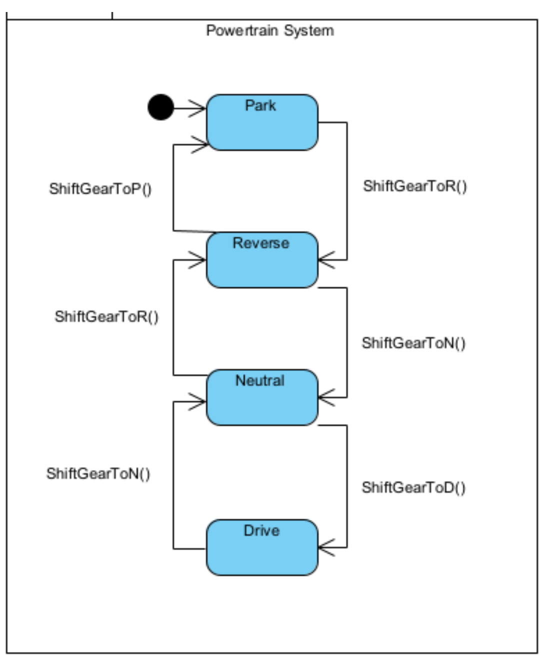

Figure 11: State diagram for the powertrain system

4.4.4 Steering System

The state diagram as seen in Figure 12 shows the different states for the steering system. The steering system begins the in off position and will move to the on position when the system is active. The wheel will either need to turn right or left based on which movement is needed during the parking maneuver. The system will return to off when APA is deactivated.

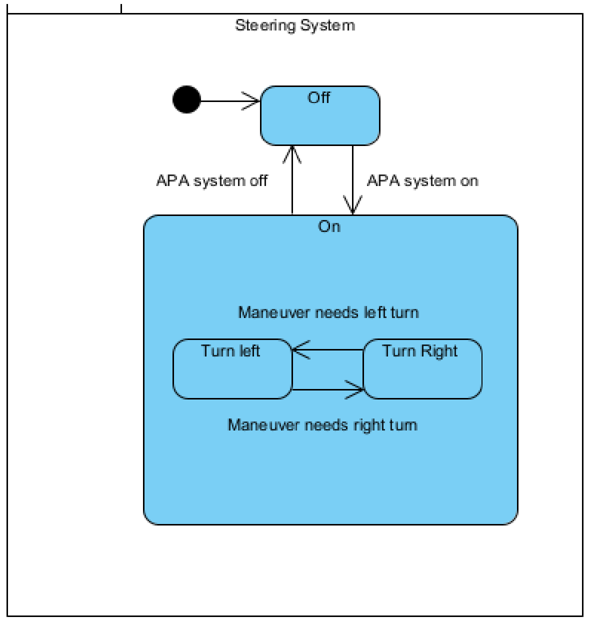

Figure 12: State diagram for the steering system

4.4.5 Position System

The state diagram as seen in Figure 13 shows the different states for the position system. The position system begins in the off position and will turn on with the APA system. It will return off when APA has deactivated.

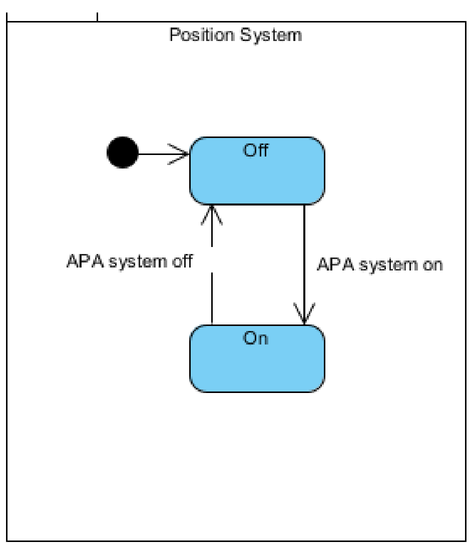

Figure 13: State diagram for the position system

4.4.6 Park Control System

The state diagram as seen in Figure 14 shows the different states for the park control system. The system starts in the off position and moves on when APA is activated. When it is on, it is either calculating trajectories or issuing commands based on that information as seen in the diagram. It will move back to the off state when APA is no longer active.

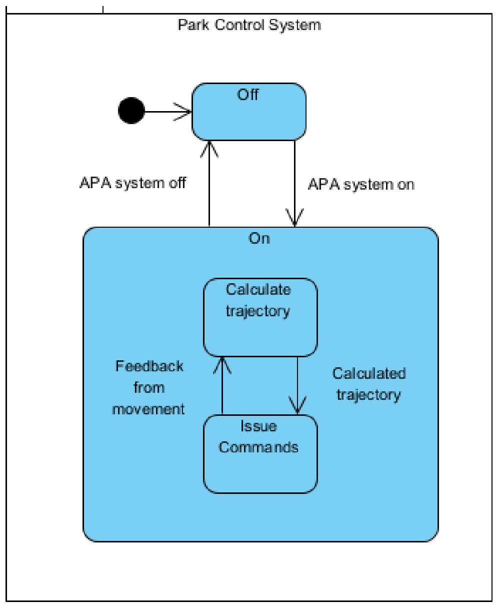

Figure 14: State diagram for the park control system

4.4.7 Camera System

The state diagram as seen in Figure 15 shows the different states for the camera system. The system starts in the off position and moves on with the APA system. It will turn off when APA is no longer active.

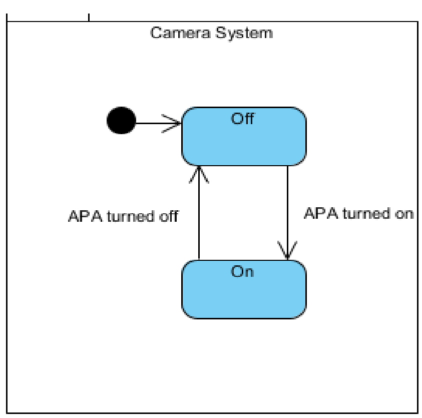

Figure 15: State diagram for the camera system

4.4.8 HMI System

The state diagram as seen in Figure 16 shows the different states for the HMI system. The system will be off until APA is activated. While the system is on, there can be warnings that may popup or pop ups where the system may need to wait on user input, as seen in the diagram. The system will turn off when APA is no longer active.

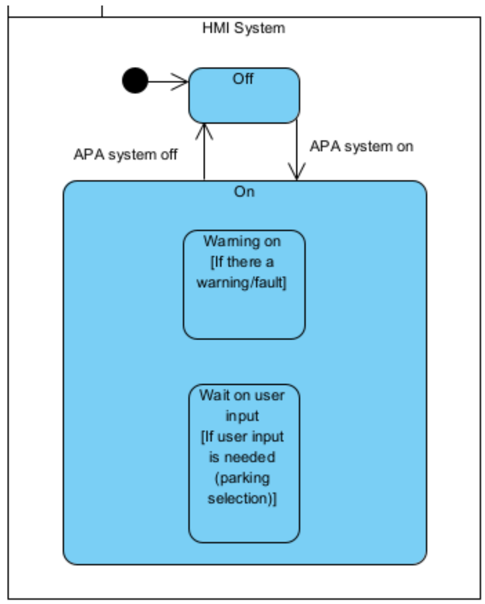

Figure 16: State diagram for HMI system

4.4.9 Ultrasonic Sensor

The state diagram as seen in Figure 17 shows the different states for the ultrasonic sensor. The sensors are off until the APA system turns on and will turn off with the APA system.

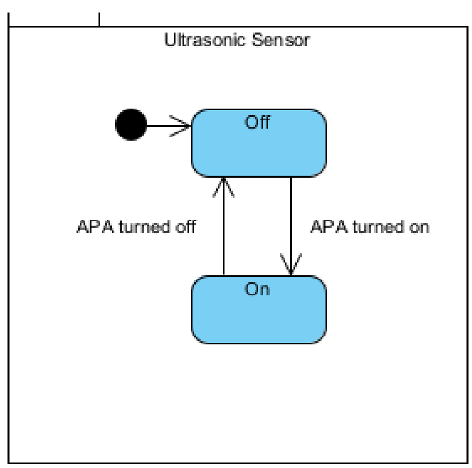

Figure 17: State diagram for the ultrasonic sensor

4.4.10 FordPass App

The state diagram as seen in Figure 18 shows the different states for the Ford Pass App. The app will be off until the user enters the app and then will enter the on state. When the user exits the app, the app will return to the off state.

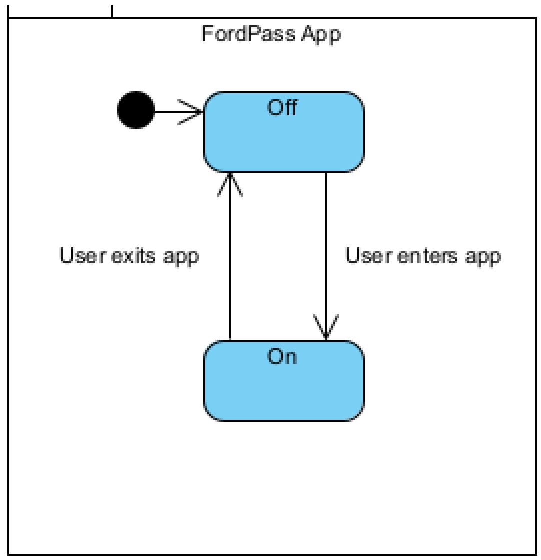

Figure 18: State diagram for the Ford Pass application

5 Prototype

5.1 How to Run Prototype

To run the prototype, navigate to our team website at https://www.cse.msu.edu/~justic35/ and click on the "Prototype" link in the navigation bar at the top. You will be given a list of scenarios to choose from. Once you click on a scenario, you will be directed to a page that has links and/or buttons to initiate the scenario. Clicking on a link or button will show you how the actors end up after the system completes the parking maneuver.

5.2 Sample Scenarios

Scenario 1:

Demonstrate a normal parking scenario in a perpendicular parking space where there is a car on either side of the parking space and the space is a valid size. The system is operated from the HMI inside the car.

In Figure 19, the scene on the left side of the arrows shows how the cars will be set up just before the parking maneuver. The car labeled “user” will be the one to perform the maneuver. When the driver turns the APA system on, the car will drive until it detects an open space. The system will alert the driver of the open spot and display a button to start parking, as shown in the second image below. Once the user chooses to start the maneuver, the system will direct the car to back into the space, and end as shown on the rightmost side of the figure.

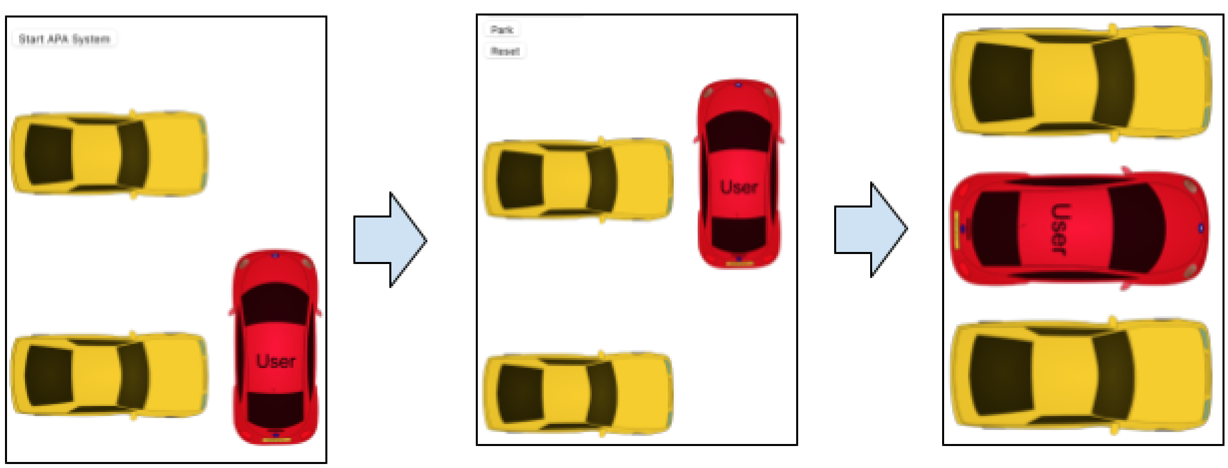

Figure 19: Parking Scenario 1

Scenario 2:

Demonstrate a normal parallel parking scenario. Assume that the length of the parking spot must be > 1.2x the length of the vehicle. The vehicle speed should be limited to < 5 mph.

In Figure 20, the scene above the arrow shows the cars before a parallel parking maneuver. After the user starts the operation, the system will direct the user car to parallel park between the two other cars. The maneuver will end with the cars in the positions seen below the arrow.

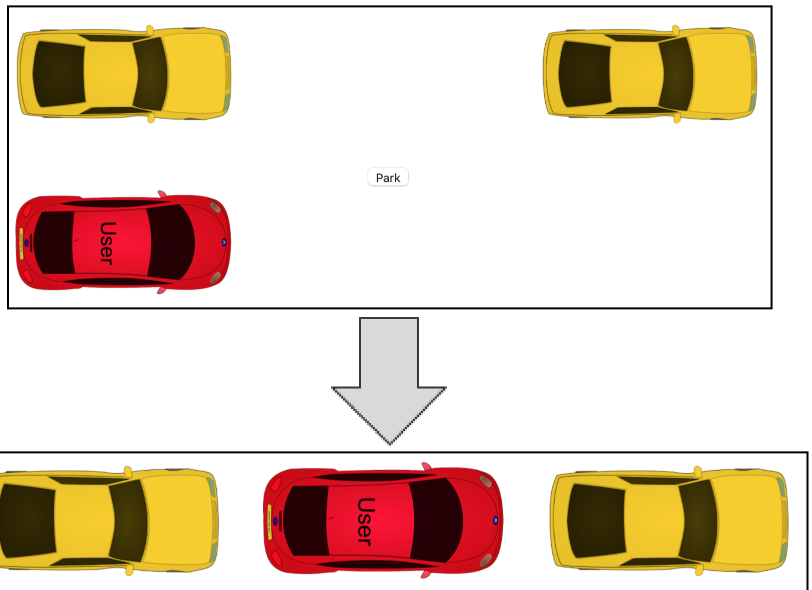

Figure 20: Parking Scenario 2

Scenario 3:

Scenario 3 demonstrates a normal perpendicular parking scenario in which the driver uses the app to park from outside the car. The app alerts the driver when it has detected a parking spot and when the maneuver is complete.

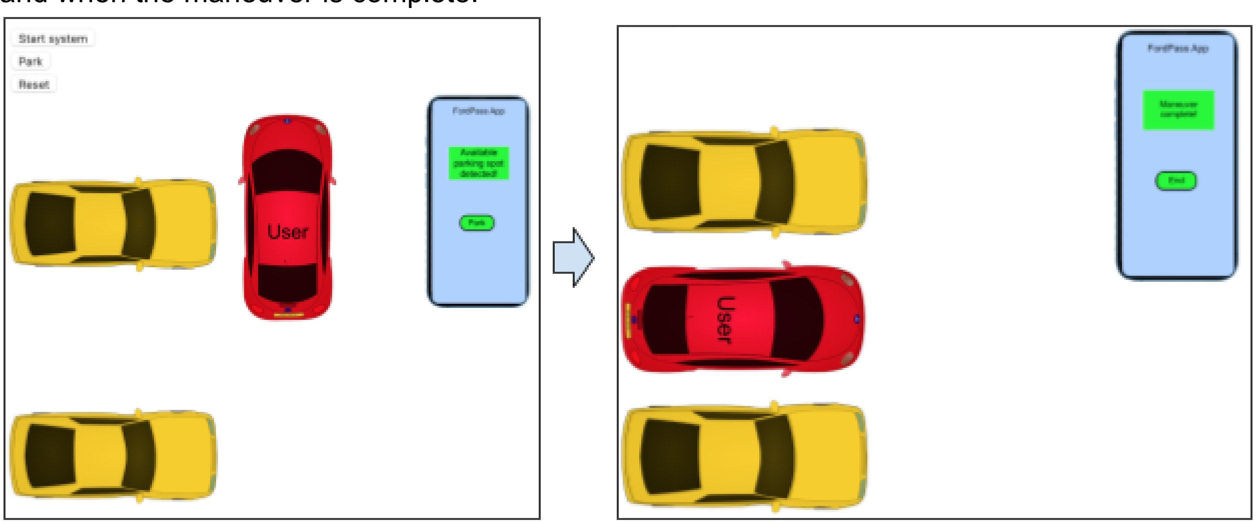

Figure 21: Parking Scenario 3

Scenario 4:

In this scenario, the driver begins a parking maneuver but notices an obstacle in the way after the maneuver begins. The driver decides to override the APA system and regains control of the vehicle, pulling out of the spot.

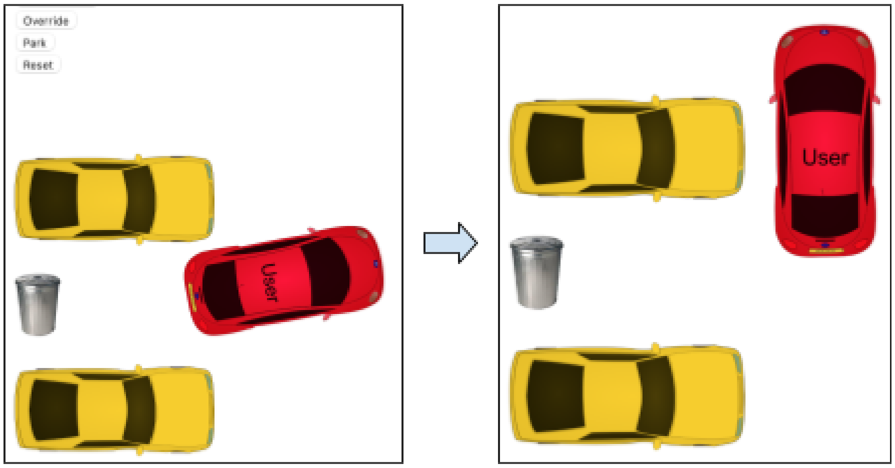

Figure 22: Parking Scenario 4

Scenario 5:

Demonstrate how weather conditions, particularly snow, impacts our systems ability to run. Snow is covering one of the cameras which doesn't allow full vision of the space around the vehicle which causes a failure in the cameras detection ability.

In Figure 23 the driver starts the system, but since one of the back cameras is covered in snow the system automatically shuts off because all subsystems are not fully functional. The driver is alerted of this, and our system gives control back to the driver.

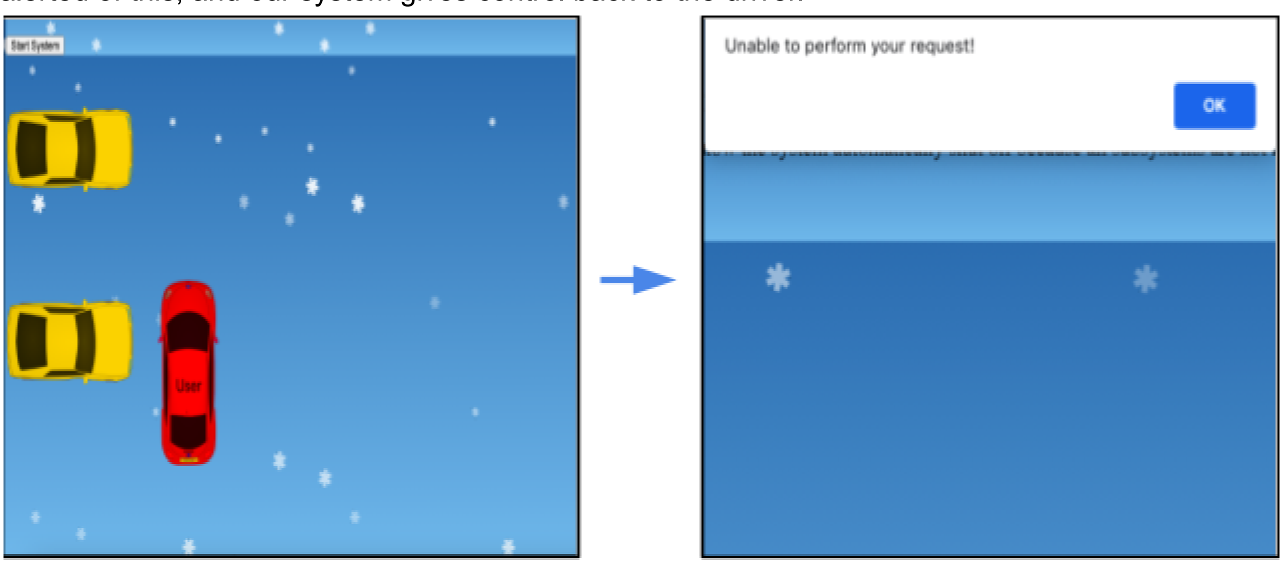

Figure 23: Parking Scenario 5

Scenario 6:

Demonstrate what happens when our system is unable to detect an empty parking space. The sensors and cameras are unable to detect any valid parking spaces within range of the car.

In Figure 24 the driver starts the system, the system searches for an open parking spot within the vehicle's range. The system can't find a space and must shut down, alert the driver, and control is given back to the driver.

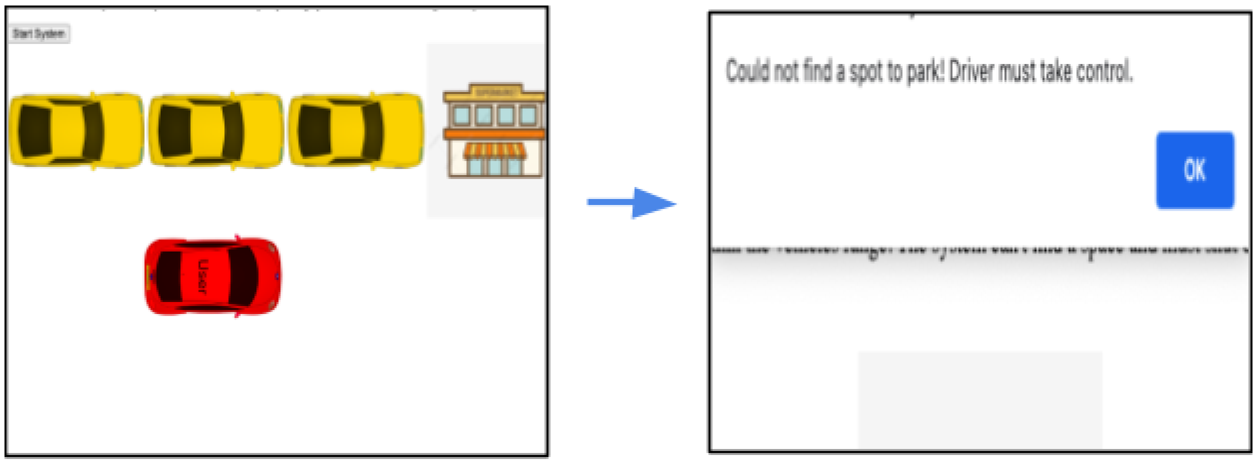

Figure 24: Parking Scenario 6

Scenario 7:

Demonstrate what happens when one of the subsystems are failing during the parking process. The failure in the braking system is detected when the driver activates the APA system via the HMI.

In Figure 25 the driver starts the system and the braking system begins to fail. The system alerts the driver of the space and prompts the driver to park.

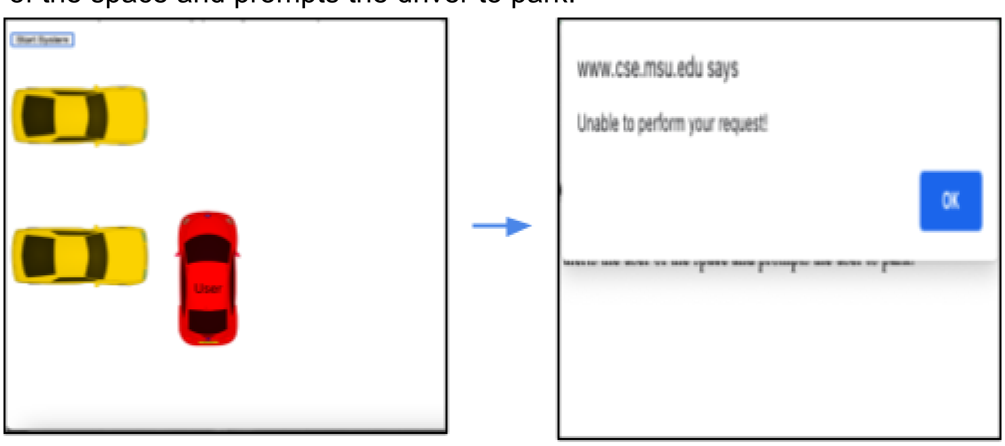

Figure 25: Parking Scenario 7

Scenario 8:

Demonstrate the confirmation process before the driver uses the FordPass application. In order to use the FordPass App, the driver must confirm their identity and their vehicle.

In Figure 26 the driver starts the system via the FordPass App, and must confirm information to prove their identity.

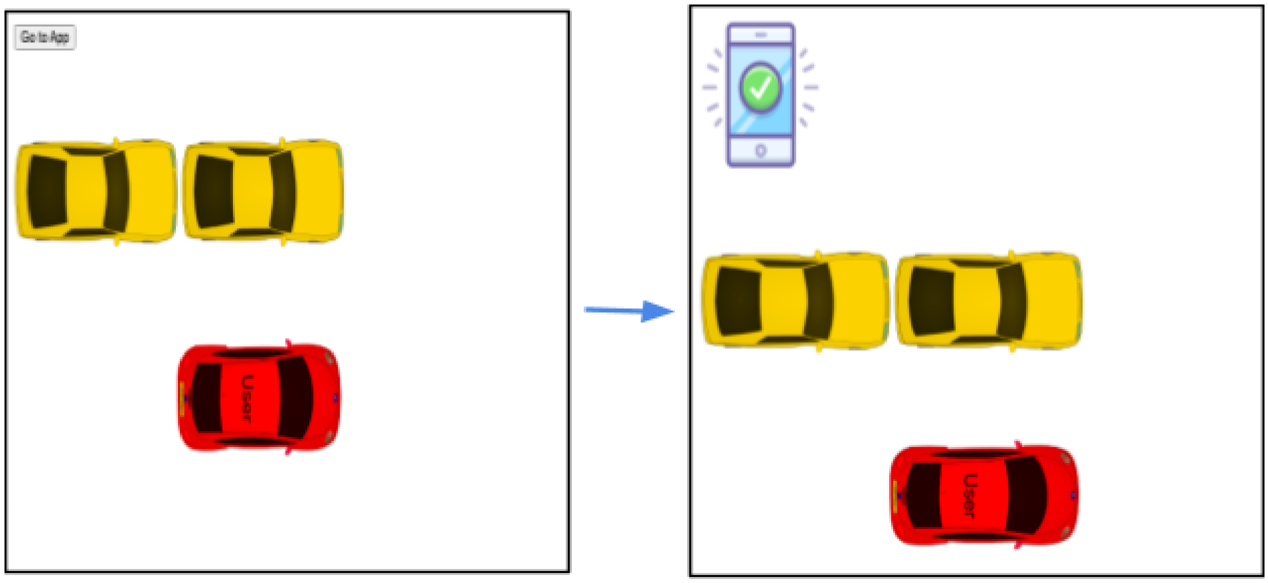

Figure 26: Parking Scenario 8

6 References

[1] E. Davidson, “Active Park Assist”, 2022.

[2] T. Agbebi, A. Justice, J. Kippe, S. Ravipati, A. Zeitoun, “ Active Park Assist 1 ”, *Team Page,* 2022. [Online]. Available: https://www.cse.msu.edu/~justic35/

7 Point of Contact

For further information regarding this document and project, please contact **Prof. Betty H.C. Cheng** at Michigan State University (chengb at msu.edu). All materials in this document have been sanitized for proprietary data. The students and the instructor gratefully acknowledge the participation of our industrial collaborators.